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Individual Differences and Theory in a Motor Learning Task

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Individual Differences and Theory in a Motor Learning Task

David Zeaman and Herbert Kaufman
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TRADITIONALLY, the study of individual differences has been the domain of the differential psychologist and not the S-R behavior theorist. Because the methods and terminologies of these two types of psychologists are so dissimilar, the empirical knowledge provided by one has not been readily interpretable by the theories of the other. The student of Thurstone, for example, speaks a language different from that of the follower of Hull. A differential psychologist usually attempts to discover clusters of correlations among response measures which he relates to *factors* having varying degrees of generality. The behavior theorist, in contrast, typically studies families of equations relating response to stimulus variables, and attempts to relate these, in turn, to *theoretical constructs* of a presumably general nature. Certainly, no simple equivalences exist between the factors and the theoretical constructs, and while complex analogies might be drawn between them, the result is seldom sufficient to bring the theories to bear on the data of individual differences with any semblance of rigor. This lack of interplay is unfortunate because at least one S-R theory has something to say about how individual differences should behave. A way to attack the problem would be to undertake the investigation of individual differences using methods and terminologies appropriate to a particular S-R theory. The studies which follow do relate some of the individual differences found in a motor learning task to theoretical constructs in Hull's system (2, 3).

EXPERIMENT I

According to Hull, individual differences may affect the various constants in the equations which represent his postulate set, but they leave invariant the form of these equations (3, pp. 115-117). This would mean, for example, that in his equation for the growth of habit strength (H)[1] as a function of number (N) of reinforcements the constants Ho, m, and i (controlling the initial strength, final level,[2] and rate of rise of habit strength, respectively) would possibly vary among individuals and species. The exponential form of this equation, however, would not be expected to change.

$$H = (m - Ho)(1 - e^{-iN}) + Ho \qquad [1]$$

If habit strength were a directly observable datum, empirical confirmation

[1] Hull's symbol for habit strength is $_SH_R$. For convenience we will omit subscript letters for this and all other constructs, where it can be done without confusion.

[2] In the 1951 revision of theory, the final level of habit (m) is set equal to unity when reaction potentials are quantified by a paired-comparisons procedure. This procedure was not used in the present study, so we have retained the possibility that m may vary among individuals. Since it was not found to do so, m may be replaced by unity in Equations 1 and 6 without altering our final analysis.

of this view would consist of the demonstration that any and all individual learning curves are adequately fitted by the above equation within the generously wide limits permitted by individual variation in the magnitudes of the three constants. But habit strength is not directly related to behavior, and this fact produces complications which prevent direct empirical check. In theory, habit strengths interact with drives and other factors to produce excitatory potentials, which in turn interact with inhibitory potentials and an oscillatory factor before affecting behavior. Each step in this chain is put into equation form by Hull, and each step involves additional equation constants capable in principle of varying from subject to subject.

With individual differences entering at so many possible places in a theoretical superstructure, it becomes a problem to identify a given empirical individual difference with the correct theoretical source, although it is necessary to establish such a correspondence if the theory is to be tested. Solutions to the problem will obviously require coordinated programs of research in every area in which the theory is applied. A beginning of one such program is made here with a theoretical and empirical analysis of the individual differences in starting levels of performance found in a commonly investigated motor task.

When subjects are given the novel perceptual motor task of writing the letters of the alphabet upside down as quickly as they can, rather wide individual differences appear in their first trial scores—the number of letters printed in 30 seconds. To enter Hull's theory with such scores, we assume that they represent one of his four performance measures: latency, amplitude, probability, or resistance to extinction. The most reasonable choice is amplitude of response (A). Next, we work backwards from this final consequent variable to the antecedent theoretical factors. Amplitude is linearly related to momentary effective reaction potential ($\dot{\bar{E}}$).[3]

$$A = h'\dot{\bar{E}} - i' \qquad [2]$$

A simple subtractive relationship combines effective reaction potential ($\bar{E}$) and an oscillatory potential (O) to form $\dot{\bar{E}}$.

$$\dot{\bar{E}} = \bar{E} - O \qquad [3]$$

And $\bar{E}$ is the difference between reaction potential (E) and total inhibition ($\dot{I}_R$).

$$\bar{E} = E - \dot{I} \qquad [4]$$

Continuing, E is equal to the product of the following variables: habit strength (H), drive (D), a delay of reinforcement factor (J), an incentive factor (K), and a stimulus-intensity component (V).

$$E = H \cdot D \cdot J \cdot K \cdot V \qquad [5]$$

Combining Equations 2, 3, 4, and 5 and substituting for H its equivalent in Equation 1, we have

$$A = h'\{[(m - Ho)(1 - e^{-iN}) + Ho] \cdot D \cdot J \cdot K \cdot V - O - \dot{I}\} - i' \qquad [6]$$

Equation 6 indicates that empirical individual differences in A could be due to individual differences in one or more of 11 theoretical variables, h', m, Ho, i, D, J, K, V, O, İ and i'. Our method of

[3] There is a minimal value L of $\dot{\bar{E}}$ termed the reaction threshold below which no reaction is observed. Individual differences in threshold values could not have been responsible for any of our individual differences in starting level, because all of our subjects performed at suprathreshold strength on every trial. This factor can therefore be disregarded in the analysis.

discovering which of these is the correct source consists of (*a*) grouping individuals who have the same score on the first trial; (*b*) varying the number of practice trials (N); (*c*) observing the relative changes in mean score of these groups over the course of practice; and (*d*) comparing these changes with those that would be produced by individual differences in each of the 11 theoretical variables.

Consider first the possibility that the starting differences are those of habit strength. Different amounts of practice prior to the experiment proper would be represented by differences in *Ho*. If all other factors are constant, Equation 6 tells us, the effect of *Ho* differences would be washed out as training proceeds. Figure 1A illustrates the gradual convergence of three groups having different values of *Ho*. If all subjects have the same amount of previous practice, but different final levels of habit growth (m), there would be a gradual divergence of the starting groups followed by a tendency to become parallel as the different asymptotes are approached. Figure 1B shows learning curves for three groups having widely different m values, but a constant, low number of previous reinforcements. An analogous plot of three groups with widely varying rates of learning (i) is given in Fig. 1C. Here

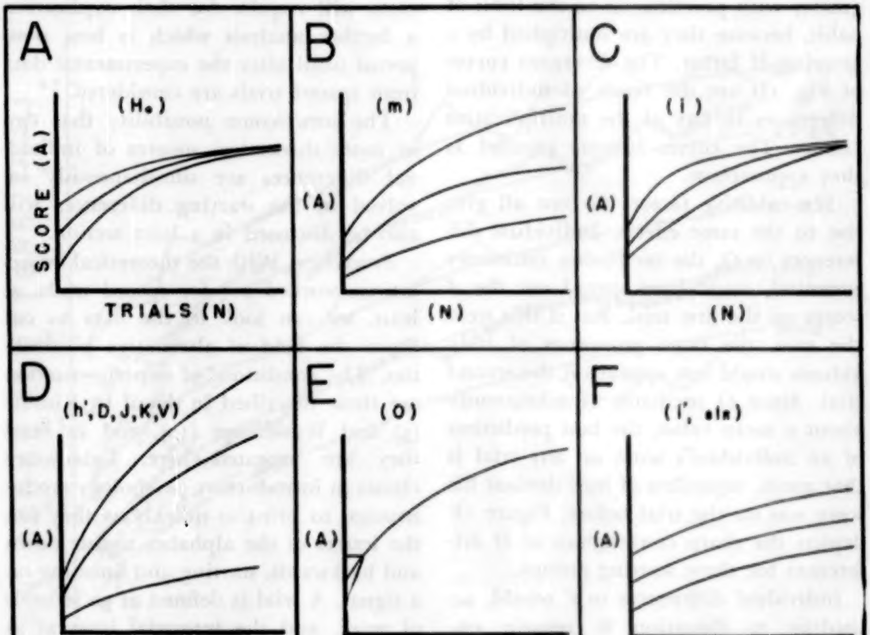

Fig. 1. Theoretical Curves. A composite graph showing what would happen to starting differences during practice if they represented individual differences in the theoretical parameters lettered above the curves.

there is gradual divergence followed by convergence.

Consider next the possibility that differences in habit strength are not involved at the outset. Instead, the subjects come into the situation with a low, approximately constant amount of habit strength, either from small amounts of prior practice, or more likely, from generalization from writing the alphabet in the usual way. Starting differences in A must then be attributed to the remaining theoretical sources of variation. There are two classes of these: the multiplicative factors h', D, J, K, V, and the additive factors O, I, i'. Individual differences due to any member of the first class of variables become greater and greater with practice, up to the limit of habit, because they are multiplied by a growing H factor. The divergent curves of Fig. 1D are the result of individual differences in any of the multiplicative factors. The curves become parallel as they approach m.

The additive factors do not all give rise to the same effects. Individual differences in O, the oscillating inhibitory potential, could have spread out the A scores on the first trial. But if this were the case, the same groupings of individuals would not appear on the second trial. Since O oscillates asynchronously about a mean value, the best prediction of an individual's score on any trial is that mean, regardless of how deviant his score was on the trial before. Figure 1E depicts the sharp convergence of O differences for three starting groups.

Individual differences in i' would, according to Equation 6, remain unchanged throughout learning, thus producing a family of parallel learning curves, as shown in Fig. 1F. A glance at Equation 2 shows that the constant i' (together with h) controls the manner in which the excitatory potential ($\dot{E}$) is translated into action.

The remaining possibility is that of I. Since this, too, is an additive factor, individual differences here would lead to parallel learning curves of the type shown in Fig. 1F, provided that I does not change during training. Widely spaced trials would fulfill this provision, and the degree of spacing necessary to render constant both the reactive and conditioned inhibitory components of I is known experimentally (5). Under massed trials, on the other hand, I would undergo progressive accumulation. A set of parallel curves could then no longer be predicted. The courses of change expected under massed conditions will require for their explication a further analysis which is best postponed until after the experimental data from spaced trials are considered.

The unwelcome possibility that two or more theoretical sources of individual differences are simultaneously involved in the starting differences will also be discussed in a later section.

Procedure. With the theoretical expectations worked out for spaced trials, at least, we can look to the data to cut down the field of alternative possibilities. The conditions of experimentation are those described in detail by Kimble (5) and Wasserman (10), and in brief they are repeated here. Laboratory classes in introductory psychology are instructed to print as quickly as they can the letters of the alphabet upside down and backwards, starting and finishing on a signal. A trial is defined as 30 seconds of work, and the intertrial interval as 30 seconds of rest, which is generally regarded on the basis of evidence as sufficient to prevent cumulation of inhibition (6). A score is the number of letters printed during a trial. Forty consecutive

TABLE 1

THE STARTING SCORES AND SIZES OF THE SIX EXPERIMENTAL GROUPS RUNNING UNDER SPACED CONDITIONS

Starting Score Interval	N
14–15	9
17–18	7
21–22	7
25–26	8
29–30	5

spaced trials complete the task.

Under these conditions we have available for analysis the data of 80 subjects with starting scores ranging from 10 to 30 about a mean of 19. In forming the different subgroups on the basis of starting scores, we tried to maximize these characteristics: (*a*) homogeneity within the groups, (*b*) heterogeneity among the groups, and (*c*) size of the groups. Since these factors tended to work against each other, it was necessary to effect a compromise. This was done by inspecting the distribution of starting scores, which, although of an over-all normal shape, had several gaps and clusters that could be used to advantage in maximizing the above factors. Five relatively dispersed groups of small but adequate size were found whose within-group variation was restricted to a single pair of adjacent scores. Table 1 gives their location and size.

Results. Learning curves for the five groups are shown in Fig. 2. The

FIG. 2. Empirical spaced-practice curves for the various starting groups. The starting scores included within each group are identified at the end of each function. The curves are regarded as parallel.

mean score of each group is plotted for every other trial. Running through each set of points is a common function that has been merely moved up or down on the ordinate to accommodate the various starting points. The fact that a single smooth curve gives a fair approximation to all the empirical curves emphasizes their parallelism. The deviations are not such as to suggest any systematic divergence or convergence.

Discussion. The interpretation of results follows from the marked resemblance that the empirical curves bear to the theoretical curves in Fig. 1F. If a single source of theoretical individual difference is involved, the evidence points clearly to either I or i'. Our next step is to describe a method for distinguishing between these two factors, after we have discussed the likelihood of multiple sources of individual differences.

The possibility exists that our empirical curves could have been produced by a combination of factors other than I or i', no one of which alone would cause parallel curves. For example, if the subjects who were high starters had high *Ho* (from previous practice) *and* high *D* (motivation for the task), the low starters a low *Ho* and *D*, and the middle starters middle values of each, then the expected convergence of *Ho* differences might be offset by the divergence produced by *D* differences. A family of parallel curves would result if the *D* and *Ho* factors were nicely correlated in such a way that the two opposing effects canceled each other out, leaving only the starting differences. We have no grounds as yet for ruling out this possibility and similar ones, other than the argument that these very special combinations of related pairs of divergent-convergent factors capable of yielding parallelism form a very small class in comparison with the number of possible combinations. The analysis continues on the reasonable assumption that a single source is to be discovered.

Having reduced the possibilities to either I or i', we consider now their separation. One method makes use of the fact that the inhibitory factor (I) can be varied experimentally by the massing of trials. If starting differences reflect I differences, the accumulation of more I during massed practice should tend to eliminate the differences and bring convergence of the curves. This comes about for the following reasons. Starting I differences must be due to the conditioned inhibition component of I since the reactive inhibition component has been dissipated by the enforced rest before the first trial. Growth of $_SI_R$, like that of habit, is rapid at first with deceleration to an asymptote later on. This means that subjects whose performance suffers from relatively high amounts of generalized $_SI_R$ at the outset of training will no longer be at a disadvantage, relatively, when all subjects have been brought to their $_SI_R$ asymptotes by extended mass practice. These considerations predict not only the convergence of curves but also something of the nature of the convergence. Low starters, being further along on the growth curve of $_SI_R$, will add less $_SI_R$ on each massed trial than the less inhibited high starters. The performance curve of the low starter will therefore rise more sharply (following the growth of $_SH_R$) than that of the high starter. The picture, then, during massed practice should be one of a family of learning curves having progressively flatter rates of rise, the higher the starting points.

A contrasting picture emerges from the assumption of starting differences in i' rather than I. The parallel curves ob-

served under spaced practice would also be predicted under massed, since in the general theory there is no necessary reason why subjects with different i' constants should respond differentially to the inhibition of massed trials.

A complication arises to destroy the clarity of these two alternative predictions—converging versus parallel curves—when we consider a possible source of interaction between i' and I. Subjects with high starting points owing to greater i' constants will, for this particular task, be doing more work (more letters printed per trial) than those with low starting points. In Hull's system, the inhibition brought about by massing of trials is a work-sensitive parameter. If the work differences of the various starting levels are more than negligible, then the subjects starting high because of greater i' would also generate greater I from the greater work output. A convergence of the curves would be the result. Moreover, the convergence would be of the same type as that produced by starting $_{S}I_{R}$ differences. The higher curves would be flatter because of the relatively greater increments of I at the higher work levels.

The upshot of this complication is this: if during massed trials the performance curves of the various starting groups remain parallel, then we may conclude that starting differences involve negligible work differences and, more importantly, that the theoretical source of individual difference is the constant i'; if, on the other hand, the curves converge, either i' or I could be the theoretical source, and the problem would remain unsolved.

Divergence of the curves or other outcomes would be inconsistent with our theoretical analysis and previous findings.

Summary. An attempt has been made to relate individual differences in starting scores on a commonly studied motor task to a theoretical factor in Hull's system. Analysis of the changes in individual differences during the course of spaced practice reduced the field of possible theoretical factors from eleven to two. A method was proposed by which this number might possibly be further reduced to one. It requires observation of changes in individual differences during massed practice.

Experiment II

Proceeding from the rationale described above, we propose in the present experiment to follow the changes in individual differences throughout the course of massed practice.

Procedure. In all relevant respects the procedure duplicates that of Experiment I, except for the intertrial interval. A completely massed condition was achieved by allowing zero seconds of rest between the 30-second work periods. The result is 20 minutes of continuous printing divided up into 40 30-second trials for purpose of scoring only. In this way the accumulation of I is maximized and a good test of theory provided. New subjects were again selected from our introductory laboratory classes. The number of subjects in each group is given in Fig. 3.

Results. Figure 3 indicates clearly enough that starting differences tend to be lost during massed practice. The curves gradually converge. Furthermore, they converge in a manner described by part of the theory. The higher starting-point curves exhibit flatter slopes than the curves lower on the graph.

Some additional features of the empirical curves worthy of note are these: (*a*) the over-all level of the curves on the

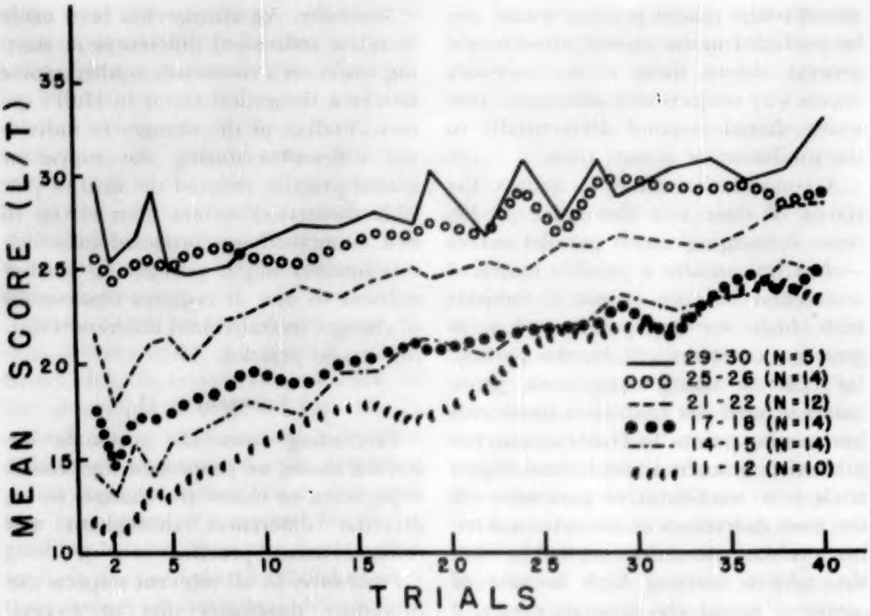

FIG. 5. Massed-practice curves for the different starting levels. The curves tend to converge.

ordinate is lower than during the spaced training, showing that the massing of trials effectively generated inhibition; (*b*) the second trial scores of all groups were uniformly low, showing the effect of some as yet unidentified decremental factor. This latter effect has been observed before (5, 10) and attributed to "confusion" of the subjects. Evidence to be presented later will rule out this explanation.

Discussion. The nonparallel form of the curves means that there are still two possible theoretical sources of the individual differences in starting scores, either I or i'. Some further means of separating these will have to be devised. We have by no means exhausted the differential consequences of these two theoretical sources. If, for example, it were feasible to assess separately the amounts of I_R and ${}_sI_R$ in our various subgroups at some intermediate stage of practice, a test of the two alternatives might be provided. The steps in the logic of the test can be enumerated: (*a*) The slow rate of rise of the high starters' curve during massed practice proves that they generate more total inhibition during massed practice than the low starters. (*b*) If i' is responsible for starting differences, we must conclude from the observed convergence that the high starters have been doing significantly more work, thus developing more I_R and consequently more ${}_sI_R$. (*c*) If I is responsible for starting differences, the high starters develop more inhibition during massed training, not because they generate more I_R, but because they come into the experiment with less ${}_sI_R$, and hence do not run into the ${}_sI_R$ ceiling or asymptote, as do the low starters with their advanced amount of generalized ${}_sI_R$ at the start. (*d*) If,

then, we measure the amount of I_R and $_sI_R$ in the subgroups at an intermediate stage of massed practice, we would expect, on the basis of the i' hypothesis, higher amounts of both I_R and $_sI_R$ for the high starters, while the I hypothesis predicts that it will be chiefly the $_sI_R$ component that will distinguish the various subgroups. (*e*) It is feasible for this task to measure separately the components of I in the traditional fashion: I_R as score difference before and after a rest, $_sI_R$ as score difference of spaced and massed groups after a rest.[4]

Summary. Analysis of the changes in individual differences during massed practice failed to reveal the theoretical source of the individual differences. Another test has been proposed in which a rest period is given at an intermediate stage of massed practice.

Experiment III

Our previous discussion has led to the formulation of a test of theory. Since the success of this test depends upon estimations of I_R and $_sI_R$, it is appropriate to review in more detail some existing experimental conventions for the measurement of these quantities. Permanent or conditioned inhibition for this task has been measured by Kimble (5, 6) and Wasserman (10) as the simple difference between the scores of a spaced-practice group (trials of 30-seconds work, 30-seconds rest) and the scores of a massed-practice group (30-seconds work, zero-seconds rest) immediately after a 10-minute rest period. The rest period results in a sharp increment in the massed-group scores commonly termed a "reminiscence jump" and regarded as a measure of I_R dissipated during the rest. If the rest is given at an intermediate stage of practice, say after the twentieth trial, the reminiscence jump does not take the massed-group score up to the level of the spaced control. The amount by which it fails to do so provides us with a measure of $_sI_R$. It has been shown that by the twentieth trial, $_sI_R$ is at an intermediate stage of its growth.[5]

Procedure. The only change in procedure from Experiment II is the interpolation of a 15-minute rest between the twentieth and twenty-first trial. During the rest period the subjects were requested to refrain from either overt or covert rehearsal of the task. The population from which the new subjects were selected remained the same. The number of people in each group is indicated in Fig. 4.

Results. Figure 4 shows the effects on individual differences of a rest interval during massed trials. Before the rest a gradual tendency toward convergence of the curves can be seen, demonstrating the reproducibility of the results of Experiment II. On the trial following rest all the curves undergo the expected reminiscence jump, magnitudes of which are separately plotted in Fig. 6 as our measure of I_R. With the loss of I_R there is a

[4] These conventions have been suggested by Ammons (1), and adopted since by many experimenters.

[5] This has been shown by Kimble (5) and Wasserman (10). Recently, however, in a paper by Schucker, Stevens, and Ellis (9), it was found that no conditioned inhibition was present at any stage of practice if the definition of "trial" was changed from a specified *time* period to that of a specified *number of letters printed.* Wasserman (10) was the first to suggest and use this definition of a trial. Its adoption reduced but did not eliminate $_sI_R$ for his data. We have retained the old convention of a *time* trial because it seems to us to give a better index of the number of reinforcements received by the subject. Since the subject is instructed that his score is the number of letters he can print within a time period, it is at the end of this time period (not after each letter) that he gets his knowledge of results—the vehicle, we presume, of reinforcement in this task.

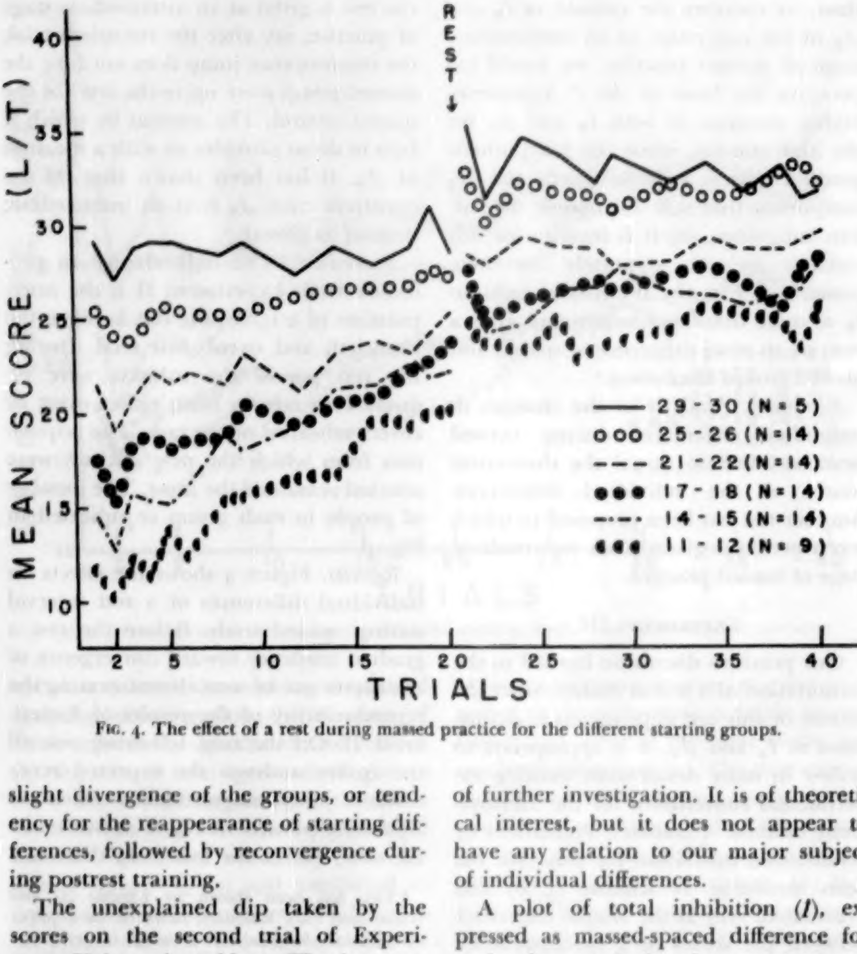

FIG. 4. The effect of a rest during massed practice for the different starting groups.

slight divergence of the groups, or tendency for the reappearance of starting differences, followed by reconvergence during postrest training.

The unexplained dip taken by the scores on the second trial of Experiment II is again evident. The interpretation of this dip as a failure of subjects to understand fully the procedure is made unlikely by the appearance of the same phenomenon on the second postrest trial (trial 21). This minor effect seems not to be an artifact but rather an indicator of a genuine, short-life decremental factor associated with the very early stages of postrest massing at any point in practice. The task-to-task generality of this finding should be the topic of further investigation. It is of theoretical interest, but it does not appear to have any relation to our major subject of individual differences.

A plot of total inhibition (*I*), expressed as massed-spaced difference for each subgroup during the present experiment, is shown in Fig. 5. The direct relationship between starting score and magnitude of *I* is obvious from the tenth trial on. On the first postrest trial (trial 21) reactive inhibition is assumed to be absent, leaving just $_{S}I_{R}$. The scores of each subgroup on this trial are plotted separately in Fig. 6 to show the relationship of starting score and conditioned inhibition. Following the drop in inhibition after the rest period, a second rise

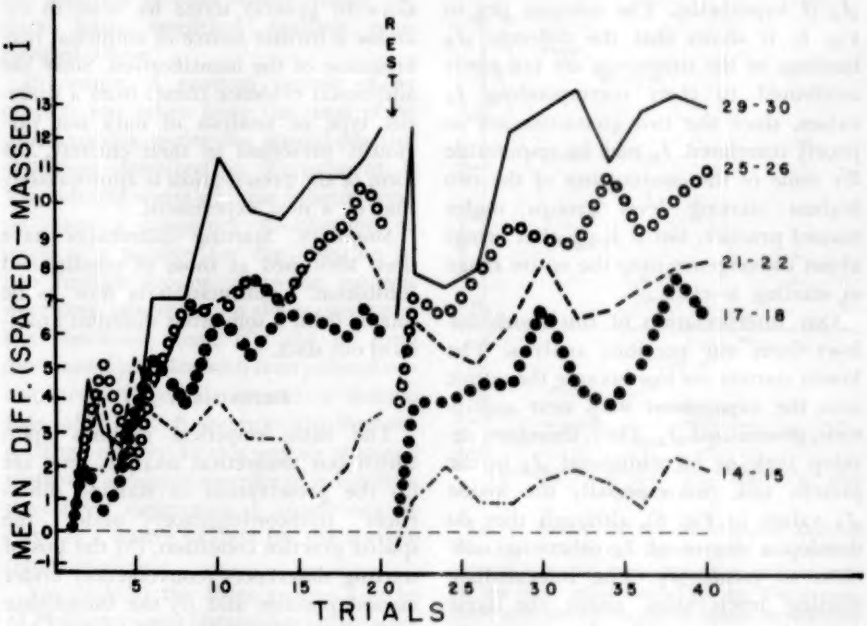

FIG. 5. Empirical measures of total inhibition ($\bar{I}$) over practice for the different starting groups. The measures here are the differences between corresponding points of Figs. 2 and 4. Immediately after the rest period the points become indices of only conditioned inhibition.

in $\bar{I}$ is seen for most groups, continuing until the fortieth trial. During this period I_R is regenerated and ${}_SI_R$ continues its growth.

Figure 6 answers our major theoretical question by showing that it is chiefly ${}_SI_R$ and not I_R that distinguishes the subgroups. The magnitude of ${}_SI_R$ is directly related to starting score. A rough description of this relationship would put ${}_SI_R$ proportional to starting level. I_R, in contrast, is not as simply related to starting level. The highest starting level (the 29-30 level) has significantly more I_R than any other point, but the first four values in the function show an inverse rather than direct relation to starting level.

Discussion. The question to which this test was to provide an answer can be phrased thus: are the different ${}_SI_R$ loadings of the subgroups attributable to their respective I_R loadings (i' hypothesis) or are they due to starting differences in

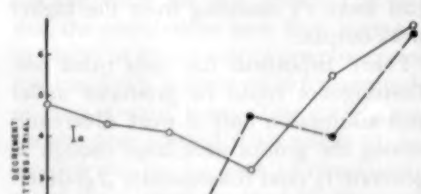

FIG. 6. The relationships to starting level of temporary and conditioned inhibition at trial 21. The derivation of the measures is discussed in the text.

${}_sI_R$ (I hypothesis). The solution lies in Fig. 6. It shows that the different ${}_sI_R$ loadings of the subgroups are not easily attributed to their corresponding I_R values, since the two quantities are so poorly correlated. I_R may be responsible for some of the convergence of the two highest starting level groups under massed practice, but it is ${}_sI_R$ that brings about convergence over the entire range of starting levels.

Our interpretation of this result follows from our previous analysis. The lowest starters are low because they come into the experiment with near asymptotic, generalized ${}_sI_R$. They, therefore, develop little or no additional ${}_sI_R$ in the present task (see especially the lowest ${}_sI_R$ values in Fig. 6), although they do develop a degree of I_R otherwise sufficient to create ${}_sI_R$. The intermediate starting levels show about the same amounts of I_R as the lower starting groups but an intermediate degree of ${}_sI_R$. The highest starting levels produced the highest amount of ${}_sI_R$, not only because they had the least amount to start with (allowing the most room for new ${}_sI_R$—the only kind measured by our technique) but also, perhaps, because they had more I_R resulting from the higher work output.

The i' hypothesis has been ruled out. Convergence could be produced under this assumption only if work differences among the groups were large enough to generate I_R (and consequently ${}_sI_R$) differences. The fact that I_R differences among most of the subgroups were small and unsystematic eliminates this possibility.

With the theoretical identification of starting differences as those of conditioned inhibition (${}_sI_R$), the purpose of the present experiment is fulfilled. Before we state our summary and conclusions in general terms we wish to examine a further source of empirical confirmation of the identification. Since the additional evidence comes from a different type of analysis of data not previously presented in their entirety, the form of the presentation is appropriately that of a new experiment.

Summary. Starting differences have been identified as those of conditioned inhibition. Confirmation is now to be sought from a somewhat different analysis of our data.

Experiment IV

The basic empirical findings upon which our theoretical analysis rests are (*a*) the preservation of starting differences (nonconvergence) under the spaced practice condition, (*b*) the loss of starting differences (convergence) under massed practice and (*c*) the incomplete restitution of starting differences after an interpolated rest in massed practice. These effects were established by inspecting the changes in mean scores of small groups, homogeneous within groups with respect to starting scores but heterogeneous between groups. No attention was given to the within-group scatter around the means which, although small on the first trial, was not negligible. This means that we have been ignoring an aspect of individual differences in starting level. Also, it is possible that some distortion may have been introduced by our selection of groups. To overcome these deficiencies we have (*a*) made a correlational analysis of individual differences in starting level which considers within- as well as between-group variation, and (*b*) based our selection of cases on a random sampling procedure.

It is our purpose to discover whether or not the changes in mode of analysis

and selection of cases would change the three basic empirical findings enumerated above.

Procedure. A random sample of 61 subjects was taken from the total of 80 who had run under the spaced-practice condition described in Experiment I. The starting scores of these subjects were put into a frequency distribution to serve as a pattern for the selection of two further groups. Sixty-one subjects were then selected from the massed-practice condition (Exp. II), and 61 from the massed-practice-with-interpolated-rest condition (Exp. III) in such a fashion that all three frequency distributions matched exactly. In this way we obtained matched, unbiased samples of subjects in the three experimental conditions to serve as a source of data for the correlational analysis.

For each of the three groups a series of Pearson r's was obtained relating starting score with later scores: for the massed group, first trial with all 39 subsequent trials; for the massed-with-rest group, first trial with all 39 subsequent trials, also; and for the spaced group, first trial with every fifth subsequent trial. The immediate object of the analysis was to discover how an individual's initial rank within a group was preserved throughout the course of training.

Results. The top half of Fig. 7 shows how first trial scores correlate with subsequent trial scores. For the spaced group, the first trial score starts off as a good predictor of later rank, and although it gradually diminishes in this capacity, it remains a moderately good predictor over trials. Initial rank is also well preserved over early trials for the massed and massed-with-rest groups, but the original order tends to be rapidly lost during the middle and later stages

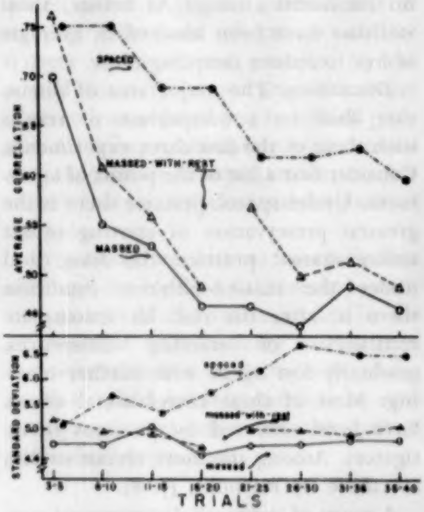

FIG. 7. Results of the correlational analysis. The top half of the figure shows the correlations of first trial score with those of later trials for the three experimental groups. The correlations have been averaged by blocks for stability. The lower half of the figure shows the standard deviations of the three groups over blocks of trials.

of practice. The large upward jump in the trend of correlations of the massed-with-rest group after the twentieth trial indicates a restoration of some of the starting order for this group. The fact that the correlations have been averaged in blocks of five to reduce sampling error has cut down slightly on the magnitude of this upward jump. The correlations for the first postrest trials (trials 21, 22, and 23) are .59, .54, and .54 respectively, all of them below the level of the spaced group at that stage of practice.

The lower half of Fig. 7 gives the standard deviations of the distributions of scores for each group over learning. For the spaced group, variability increases with the mean score over practice, while the other two groups show little or

no consistent change. As before, these statistics have been blocked in averages of five to reduce sampling error.

Discussion. The major area of discussion shall be a comparison of results with those of the first three experiments. Consider first a list of the points of agreement. Under spaced practice there is the greatest preservation of starting order; under massed practice, the least; and under the massed-with-rest condition there is, after the rest, an incomplete restitution of starting differences, gradually lost again with further massing. Most of these correlational effects have been observed by previous investigators. Among the more recent studies are those by Reynolds (7, 8).

A point of apparent disagreement concerns the falling nature of the correlation curve for the spaced group—an indicator that some individuals have definitely lost their starting position. In contrast, it will be recalled that the mean curves for this condition remain parallel as an indicator of no loss of starting identity. The contradiction is only apparent, however. The two findings are quite congruent, and might have been expected for certain theoretical and empirical reasons. Let us review them.

Experiment I showed that, on the average, groups of like starters under spaced practice retained their starting position. Experiment IV shows that a fair number of individuals do not keep their starting order. This could come about if individuals varied randomly about their starting rank order, and gradually increased in the magnitude of their random oscillation over practice. This would allow a group of like starters to preserve its mean rank over practice (parallel mean curves) and at the same time overlap more with neighboring groups (decreasing correlation curve). Examination of the curve of standard deviations in Fig. 7 shows that the spaced practice group does in fact increase its variability over practice, a fact which has been demonstrated before by Kientzle (4). A theoretical basis for this type of random variation exists in Hull's system in the construct of oscillatory potential (*O*). Properties of *O* are such as to account for the observations. First, it is postulated to behave essentially like a source of random variation that will not systematically affect central tendencies of groups of "like" individuals (those having the same evocation potential), and secondly, it has been found empirically in basic investigations of *O* that its magnitude becomes larger later in learning (11). The correlational analysis is sensitive to this added source of variation, and its presence is recorded on this measure as a loss of starting identity. What the correlations do not tell us is that this loss is only momentary for the individual and not at all a property of group measures of like individuals.

The massed groups must also be subject to this added source of oscillatory variability. An obvious reason why it does not show up as an increase in standard deviations for these groups is that the means of the different starting groups are converging (for reasons already given) thus tending to shrink total variability. Apparently the two tendencies counteract each other, leaving the observed flat variability functions of Fig. 7 for these conditions. If these interpretations are correct, the results of this experiment add further empirical confirmation to our previous theoretical analysis.

General Summary and Conclusions

These studies have succeeded in relating individual differences in starting

scores on a commonly studied motor task to a single theoretical factor in Hull's system. Analyses of the changes in individual differences during the course of spaced and massed practice, as well as changes produced by interpolated rest during massed practice, reduced the field of possible theoretical factors from eleven to one. Individual differences were discovered to be those of generalized conditioned inhibition ($_{s}I_{R}$), interpretable as a previously learned tendency to rest during assigned periods of prolonged work.

The empirical findings upon which the theoretical analysis rests were as follows: (*a*) the preservation of starting differences of groups of like starters under spaced practice, (*b*) the gradual loss of starting differences of groups of like starters under massed practice, (*c*) the partial recovery of starting differences after an interpolated rest in massed practice. A further confirmation of the results and theoretical interpretations was obtained from a correlational analysis of the data.

In general, we wish to conclude that although the top-heavy theoretical superstructure of Hull's system makes its use cumbersome and unwieldy in this area, it nevertheless can be deductively elaborated to yield testable predictions of a semiquantitative nature in the field of individual differences.

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